PB-240 312

SILVER LAKE, MC LEOD COUNTY, MINNESOTA

Pacific Northwest Environmental Research Laboratory

Prepared for:

National Environmental Research Center, Corvallis
National Environmental Research Center, Las Vegas
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16. ABSTRACT
Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivded according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
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REPORT
ON
SILVER LAKE
MCLEOD COUNTY
MINNESOTA
EPA REGION V
WORKING PAPER No. 125

WITH THE COOPERATION OF THE
MINNESOTA POLLUTION CONTROL AGENCY
AND THE
MINNESOTA NATIONAL GUARD
NOVEMBER, 1974

1b

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Minnesota Pollution Control Agency for professional involvement and to the Minnesota National Guard for conducting the tributary sampling phase of the Survey.

Grant J. Merritt, Director of the Minnesota Pollution Control Agency, John F. McGuire, Chief, and Joel G. Schilling, Biologist, of the Section of Surface and Groundwater, Division of Water Quality, provided invaluable lake documentation and counsel during the course of the Survey; and the staff of the Section of Municipal Works, Division of Water Quality, were most helpful in identifying point sources and soliciting municipal participation in the Survey.

Major General Chester J. Moeglein, the Adjutant General of Minnesota, and Project Officer Major Adrian Beltrand, who directed the volunteer efforts of the Minnesota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

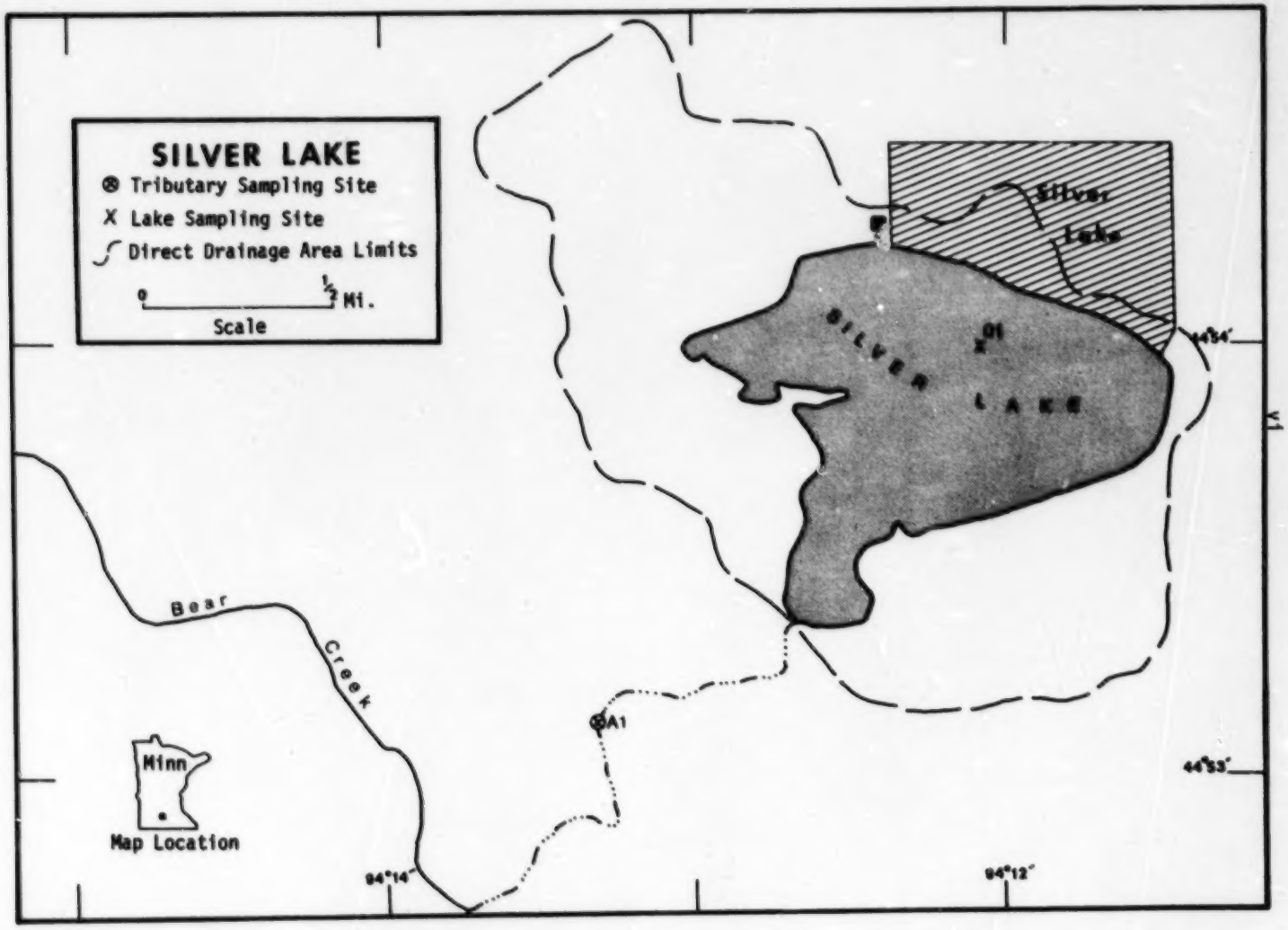
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF MINNESOTA

LAKE NAME	COUNTY
Albert Lea	Freeborn
Andrusia	Beltrami
Badger	Polk
Bartlett	Koochiching
Bear	Freeborn
Bemidji	Beltrami
Big	Stearns
Big Stone	Big Stone, MN; Roberts, Grant, SD
Birch	Cass
Blackduck	Beltrami
Blackhoof	Crow Wing
Budd	Martin
Buffalo	Wright
Calhoun	Hennepin
Carlos	Douglas
Carrigan	Wright
Cass	Beltrami, Cass
Clearwater	Wright, Stearns
Cokato	Wright
Cranberry	Crow Wing
Darling	Douglas
Elbow	St. Louis
Embarass	St. Louis
Fall	Lake
Forest	Washington
Green	Kandiyohi
Gull	Cass
Heron	Jackson
Leech	Cass
Le Homme Dieu	Douglas
Lily	Blue Earth
Little	Grant
Lost	St. Louis

LAKE NAME	COUNTY
Madison	Blue Earth
Malmedal	Pope
Mashkenode	St. Louis
McQuade	St. Louis
Minnetonka	Hennepin
Minnewaska	Pope
Mud	Itasca
Nest	Kandiyohi
Pelican	St. Louis
Pepin	Goodhue, Wabasha, MN; Pierce, Pepin, WI
Rabbit	Crow Wing
Sakatah	Le Sueur
Shagawa	St. Louis
Silver	McLeod
Six Mile	St. Louis
Spring	Washington, Dakota
St. Croix	Washington, MN; St. Croix, Pierce, WI
St. Louis Bay	St. Louis, MN; Douglas, WI
Superior Bay	St. Louis, MN; Douglas, WI
Swan	Itasca
Trace	Todd
Trout	Itasca
Wagonga	Kandiyohi
Wallmark	Chisago
White Bear	Washington
Winona	Douglas
Wolf	Beltrami, Hubbard
Woodcock	Kandiyohi
Zumbro	Olmstead, Wabasha


SILVER LAKE
Tributary Sampling Site
Lake Sampling Site
Direct Drainage Area Limits
0
½
1 Mi.
Scale
Silver Lake
SILVER LAKE
01
A1
Bear Creek
Minn
Map Location
94°14'
94°12'
44°54'
44°53'

SILVER LAKE

STORET NO. 2782

I. CONCLUSIONS

A. Trophic Condition:

Survey data and the reports of others show that Silver Lake is eutrophic. Survey limnologists noted that the lake was extremely turbid on all sampling dates (due in large part to the number of phytoplankton present; see page 6). In a 1952 report on a waterfowl and muskrat habitat survey, Minnesota Department of Conservation biologists noted that heavy algal growths were present (Johnson, 1952).

Of the 60 Minnesota lakes sampled in the fall when essentially all were well-mixed, 48 had less mean total phosphorus, 43 had less mean dissolved phosphorus, and 38 had less mean inorganic nitrogen. For all 80 lakes sampled, 91% had less mean chlorophyll a, and 95% had greater mean Secchi disc transparency.

Because of the morphometry of this water body, it is unlikely that it would be considered anything but eutrophic regardless of cultural influences. The primary beneficial use of the lake has been as waterfowl and game habitat.

B. Rate-Limiting Nutrient:

The results of the algal assay indicate Silver Lake was nitrogen limited at the time the sample was collected. Lake data indicate nitrogen limitation at all sampling times.

C. Nutrient Controllability:

During the sampling year, Silver Lake received a total phosphorus load at a rate about four times the rate proposed by Vollenweider (in press) as "dangerous"; i.e., a eutrophic rate (see page 12). Of this load, it is estimated that the Village of Silver Lake contributed 87%. It is calculated that 80% removal of phosphorus at Silver Lake would result in a loading rate of 1.4 lbs/acre/yr or 0.16 $g/m^2/yr$ (the eutrophic rate is 0.14 $g/m^2/yr$).

While the reduced loading rate resulting from 80% phosphorus removal would just exceed the eutrophic rate, it is concluded that such a level of removal would improve the trophic condition of the lake and would significantly enhance the waterfowl and game habitat potential of Silver Lake.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

A. Lake Morphometry*:

1. Surface area: 422 acres.
2. Mean depth: 4 feet.
3. Maximum depth: 7 feet.
4. Volume: 1,688 acre/feet.
5. Mean hydraulic retention time: 2.3 years.

B. Tributary and Outlet:
(See Appendix A for flow data)

1. Tributaries -

Name	Drainage area†	Mean flow†
None	-	-
Minor tributaries & immediate drainage -	1.5 mi^2	1.0 cfs
Totals	1.5 mi^2	1.0 cfs

2. Outlet -

Silver Lake Creek	2.2 mi^2††	1.0 cfs

C. Precipitation†††:

1. Year of sampling: 32.9 inches.
2. Mean annual: 27.0 inches.

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* Anonymous, 1972.
† Drainage areas are accurate within ±5%; mean daily flows are accurate within ±10%; and ungaged flows are accurate within ±10 to 25% for drainage areas greater than 10 mi^2.
†† Includes area of lake.
††† See Working Paper No. 1, "Survey Methods".

III. LAKE WATER QUALITY SUMMARY

Silver Lake was sampled three times during the open-water season of 1972 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one station on the lake and from one or more depths (see map, page vi). During each visit, a single depth-integrated (near bottom to surface) sample was collected for phytoplankton identification and enumeration; and during the last visit, a single five-gallon depth-integrated sample was taken for algal assays. Also each time, a depth-integrated sample was collected for chlorophyll a analysis. The maximum depth sampled was 4 feet.

The results obtained are presented in full in Appendix B, and the data for the fall sampling period, when the lake was essentially well-mixed, are summarized below. Note, however, the Secchi disc summary is based on all values.

For differences in the various parameters at the other sampling times, refer to Appendix B.

A. Physical and chemical characteristics:

Parameter	Minimum	Mean	Median	Maximum
		FALL VALUES		
Temperature (Cent.)	4.9	4.9	4.9	4.9
Dissolved oxygen (mg/l)	10.3	10.3	10.3	10.3
Conductivity (µmhos)	500	500	500	500
pH (units)	8.9	8.9	8.9	8.9
Alkalinity (mg/l)	186	188	188	189
Total P (mg/l)	0.284	0.310	0.310	0.336
Dissolved P (mg/l)	0.123	0.126	0.126	0.130
NO_2 + NO_3 (mg/l)	0.110	0.120	0.120	0.130
Ammonia (mg/l)	0.250	0.255	0.255	0.260
		ALL VALUES		
Secchi disc (inches)	6	10	12	12

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Number per ml
07/03/72	1. Microcystis	29,189
	2. Anabaena	21,982
	3. Lyngbya	11,622
	4. Merismopedia	7,387
	5. Chroococcus	3,514
	Other genera	9,099
	Total	82,793
08/29/72	1. Oscillatoria	26,727
	2. Lyngbya	22,727
	3. Merismopedia	9,091
	4. Microcystis	5,636
	5. Flagellates	4,909
	Other genera	9,637
	Total	78,727
10/26/72	1. Oscillatoria	25,714
	2. Flagellates	8,797
	3. Microcystis	2,256
	4. Anabaena	526
	5. Dinobryon	526
	Other genera	1,730
	Total	39,549

2. Chlorophyll a -
(Because of instrumentation problems during the 1972 sampling, the following values may be in error by plus or minus 20 percent.)

Sampling Date	Station Number	Chlorophyll a (µg/l)
07/03/72	01	277.8
08/29/72	01	48.9
10/26/72	01	51.6

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.066	0.864	25.9
0.005 P	0.071	0.864	28.2
0.010 P	0.076	0.864	25.0
0.020 P	0.086	0.864	25.8
0.050 P	0.116	0.864	22.2
0.050 P + 10.0 N	0.116	10.864	46.4
10.0 N	0.066	10.864	39.4

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Silver Lake was very high when the sample was taken. Also, the lack of significant change in yields with increased levels of orthophosphate, and the response to the addition of nitrogen alone, show that the lake was nitrogen limited.

The lake data indicate nitrogen limitation at all sampling times (all N/P ratios were less than 3/1, and nitrogen limitation would be expected).

IV. NUTRIENT LOADINGS
(See Appendix C for data)

For the determination of nutrient loadings, the Minnesota National Guard collected monthly near-surface grab samples from the tributary site indicated on the map (page vi), except for the colder months when ice cover and low flows prevented sampling. Sampling was begun in October, 1972, and was completed in September, 1973.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Minnesota District Office of the U.S. Geological Survey for the lake outlet.

In this report, outlet nutrient loads were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings. Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated by using the nutrient loads, in lbs/mi^2/year, in an unimpacted tributary of nearby Cokato Lake at station 27190l (126 lbs P and 2,924 lbs N/mi^2/yr) and multiplying by the ZZ area in mi^2.

The Village of Silver Lake declined participation in the Survey, and nutrient loads were estimated at 2.5 lbs P and 7.5 lbs N/capita/year.

A. Waste Sources:

1. Known municipal -

Name	Pop. Served	Treatment	Mean Flow (mgd)	Receiving Water
Silver Lake	694*	trickling filter	0.070**	Silver Lake

2. Known industrial - None

* Anoymous, 1973.
** Estimated at 100 gal/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	lbs P/ yr	% of total
a. Tributaries (non-point load) -		
None	-	-
b. Minor tributaries & immediate drainage (non-point load) -	190	9.5
c. Known municipal -		
Silver Lake	1,740	87.0
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	70	3.5
Total	2,000	100.0

2. Outputs -

Lake outlet - Silver Lake 1,460

3. Net annual P accumulation - 540 pounds

* See Working Paper No. 1.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	lbs N/yr	% of total
a. Tributaries (non-point load) -		
None	-	-
b. Minor tributaries & immediate drainage (non-point load) -	4,390	32.1
c. Known municipal -		
Silver Lake	5,200	38.1
d. Septic tanks - Unknown	-	-
e. Known industrial - None	-	-
f. Direct precipitation* -	4,070	29.8
Total	13,660	100.0

2. Outputs -

Lake outlet - Silver Lake Creek 9,350

3. Net annual N accumulation - 4,310 pounds

* See Working Paper No. 1.

E. Yearly Loading Rates:

In the following table, the existing phosphorus loading rates are compared to those proposed by Vollenweider (in press). Essentially, his "dangerous" rate is the rate at which the receiving waters would become eutrophic or remain eutrophic; his "permissible" rate is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic rate would be considered one between "dangerous" and "permissible".

	Total Phosphorus		Total Nitrogen	
Units	Total	Accumulated	Total	Accumulated
lbs/acre/yr	4.7	1.3	32.4	10.2
grams/m^2/yr	0.53	0.14	3.6	1.1

Vollenweider loading rates for phosphorus ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Silver Lake:

"Dangerous" (eutrophic rate)	0.14
"Permissible" (oligotrophic rate)	0.07

V. LITERATURE REVIEWED

Anonymous, 1972. Survey questionnaire. MPCA, Minneapolis.

Anonymous, 1973. Wastewater disposal facilities inventory. MPCA, Minneapolis.

Johnson, Clare L., 1952. Waterfowl and muskrat habitat survey--Silver Lake, McLeod County. MN Dept. of Conservation, St. Paul.

Schilling, Joel, 1974. Personal communication (map and report). MPCA, Minneapolis.

Vollenweider, Richard A., (in press). Input-output models. Schweiz. A. Hydrol.

VII. APPENDICES

APPENDIX A

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR MINNESOTA 10/30/74

LAKE CODE 2782 SILVER LAKE

TOTAL DRAINAGE AREA OF LAKE 2.18

TRIBUTARY	SUB-DRAINAGE AREA	NORMALIZED FLOWS JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
2782A1	2.18	0.34	0.20	0.43	1.15	2.27	2.73	1.81	0.73	1.41	0.46	0.30	0.33	1.02
2782Z7	2.18	0.43	0.24	0.52	1.12	2.15	2.75	1.73	0.66	1.34	0.41	0.27	0.38	1.00

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 2.18
SUM OF SUB-DRAINAGE AREAS = 2.18

TOTAL FLOW IN = 12.00
TOTAL FLOW OUT = 12.16

MEAN MONTHLY FLOWS AND DAILY FLOWS

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
2782A1	10	72	1.24	15	1.20				
	11	72	1.29	13	1.50				
	12	72	0.96						
	1	73	1.29	9	1.00				
	2	73	0.55	11	1.30				
	3	73	1.70	28	2.50				
	4	73	2.04	15	2.20				
	5	73	2.58	25	2.90				
	6	73	1.77	2	2.90	12	2.00		
	7	73	0.52	13	0.58				
	8	73	0.56	11	0.50				
	9	73	0.73						
2782Z7	10	72	1.18	15	1.00				
	11	72	1.14	19	1.10				
	12	72	1.04						
	1	73	1.55	9	1.30				
	2	73	0.66	11	1.50				
	3	73	2.05	28	3.00				
	4	73	1.04	15	2.10				
	5	73	2.36	25	2.70				
	6	73	1.70	2	3.00	12	2.00		
	7	73	0.50	13	0.56				
	8	73	0.51	11	0.45				
	9	73	0.73						

APPENDIX B

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 74/10/30

278201
44 53 54.0 094 12 00.0
SILVER LAKE
27 MINNESOTA

11EPALES 2111202
3 0007 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00630 NO2&NO3 N-TOTAL MG/L	00610 NH3-N TOTAL MG/L	00665 PHOS-TOT MG/L P	00666 PHOS-DIS MG/L P
72/07/03	17 40	0000	23.0	9.5	12	410	9.00	173	0.140	0.130	0.600	0.310
72/08/29	18 09	0000			6	460	9.05	181	0.010K	0.070	0.690	0.700
	18 09	0004	21.0	5.2		480	8.65	186	0.130	0.240	0.790	0.463
72/10/24	10 00	0000			12	500	8.90	186	0.110	0.250	0.284	0.123
	10 00	0004	4.9	10.3		500	8.90	189	0.130	0.260	0.336	0.130

DATE FROM TO	TIME OF DAY	DEPTH FEET	32217 CHLRPHYL A UG/L
72/07/03	17 40	0000	277.4J
72/08/29	18 09	0000	48.3J
72/10/24	10 00	0000	51.6J

J VALUE KNOWN TO BE LESS THAN INDICATED

K VALUE KNOWN TO BE LESS THAN INDICATED

APPENDIX C

TRIBUTARY DATA

STORET RETRIEVAL DATE 74/10/30

2782A1 LS2782A1
44 53 00.0 094 13 00.0
UNNAMED OUTLET OF SILVER LAKE
27083 CO #43
0/SILVER LAKE
CO HWY 24 1 MI S .25 MI E SILVER LAKE
11EPALES 2111204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
72/10/15	15 00		0.890	2.500	0.210	0.210	0.315
72/11/19	14 00		1.110	4.000	0.350	0.220	0.690
73/03/11	14 10		4.000	3.570	0.830	0.294	0.490
73/03/28	06 40		0.078	1.890	0.048	0.147	0.240
73/04/15	14 45		0.140	3.700	0.054	0.138	0.340
73/05/25	14 20		0.252	4.500	0.105	0.660	0.800
73/06/02	14 30		0.270	2.800	0.068	0.650	0.820
73/07/13	16 50		0.430	4.400	0.710	1.100	1.300
73/08/11	14 40		0.820	6.800	1.800	1.000	1.570

STORET RETRIEVAL DATE 74/10/30

278251 TF278251 P000694
44 57 00.0 094 13 00.0
SILVER LAKE
27083 CO #43
0/SILVER LAKE
SILVER LAKE
* 11EPALES 2141204
4 0000 FEET DEPTH

DATE FROM TO	TIME OF DAY	DEPTH FEET	00631 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P	50051 FLOW RATE INST MGD	50053 CONDUIT FLOW-MGD MONTHLY
73/01/15	11 00								
CP(T)-			0.632	39.000	16.000				
73/01/15	13 00								
73/02/15	11 00								
CP(T)-			0.195	65.000	27.000	7.100	13.500		
73/02/15	13 00								
73/03/15	11 00								
CP(T)-			3.000	22.000	1.900	2.400	4.800		
73/03/15	13 30								
73/04/16	11 00		1.540	21.000	3.800	2.500	5.000		
73/05/15	11 00								
CP(T)-			0.185	43.000	10.400	4.600	8.500		
73/05/15	13 00								
73/06/15	11 00								
CP(T)-			0.170	45.000	15.700	5.300	8.800		
73/06/15	13 00								
73/07/16	11 00								
CP(T)-			3.140	48.000	23.500	4.900	8.500		
73/07/16	23 00								
73/08/15	11 00								
CP(T)-			0.033	21.000	4.900	4.300	11.500		
73/08/15	13 00								
73/09/17	11 00								
CP(T)-			3.440	29.400	11.500	5.900	7.000		
73/09/17	13 00								
73/10/15	11 00								
CP(T)-			2.600	12.500	0.260	1.700	3.150		
73/10/15	13 00								
73/11/15	11 00								
CP(T)-			0.220	36.000	14.000	2.900	9.900		
73/11/15	13 00								
73/12/17	11 00								
CP(T)-			0.450	24.000	5.600	3.150	6.000		
73/12/17	12 00								
74/01/17	11 00								
CP(T)-			0.123	21.000	15.600	6.600	9.100		
74/01/17	13 00								